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Next Club Meeting
Sunday 10th November
Belviour Guides Hall
6 Silva Drive West Wodonga

Meetings commence with a BBQ (with a donation tin for meat) at 12pm with meeting afterwards
Members are encouraged to turn up a little earlier for clubroom maintenance
Call in Via VK3RWO, 146.975, 123 Hz tone

The mysterious world of VSWR
Turn to page 2 for more…

WHAT'S GOING ON IN THAT CABLE, ANYWAY?

When shown an early radio station, the viewer was heard to remark, "Why do they call it wireless? I've never seen so many wires in all my life!" The fact that "wireless" requires a lot of wires is undeniable to those of us who have ever built or maintained any kind of radio facility — from a simple CB base station to a full-power broadcast facility. Most of the "wires" you'll find behind the equipment are more than simple strands, though. If they are conveying radio frequency (RF) signals from place to place, they are really transmission lines. In this article, we'll talk about a basic element of transmission lines — the standing wave ratio, or SWR — and why it's important and how to measure it.

TRANSMISSION LINE OVERVIEW

Any conductor carrying an AC current can be treated as a transmission line, such as those overhead giants distributing AC utility power across the landscape. Incorporating all the different forms of transmission lines would fall considerably outside the scope of this article, so we'll limit the discussion to frequencies from about 1 MHz to 1 GHz, and to two common types of line: coaxial (or "coax") and parallel-conductor (a.k.a., open-wire, window line, ladder line, or twin-lead as we'll call it) as shown in **Figure 1**.

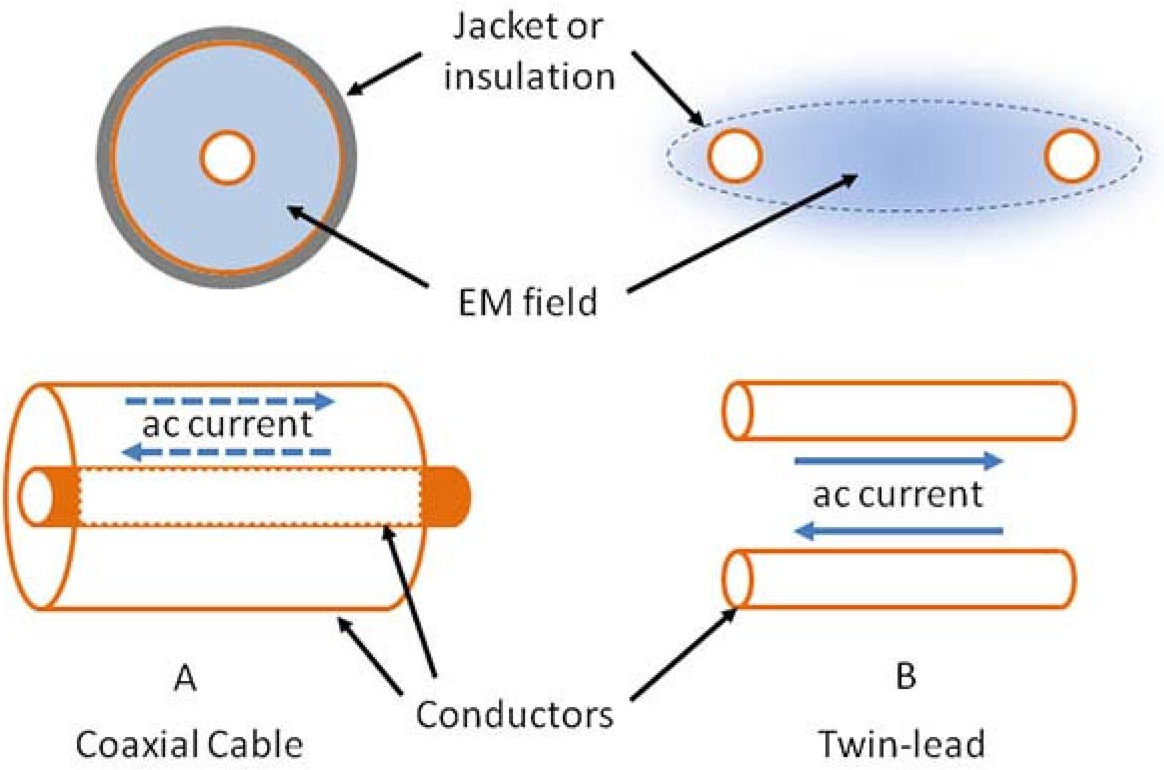


FIGURE 1. Coaxial cable **(A)** consists of a solid or stranded centre conductor surrounded by an insulating plastic or air dielectric and a tubular shield that is either solid or woven wire braid. A plastic jacket surrounds the shield to protect the conductors. Twin-lead **(B)** consists of a pair of parallel solid or stranded wires. The wires are held in place by either moulded plastic (window line, twin-lead) or by ceramic or plastic insulators (ladder line).

Current flows along the surface of the conductors (*see the sidebar on* ***"Skin Effect"***) in opposite directions. Surprisingly, the RF energy flowing along the line doesn't really flow in the conductors where the current is. It travels as an electromagnetic (EM) wave in the space between and around the conductors. **Figure 1** indicates where the field is located in both coax and twin-lead. For coax, the field is completely contained within the dielectric between the centre conductor and shield. For twin-lead, though, the field is strongest around and between the conductors but without a surrounding shield, some of the field extends into the space around the line.

This is why coax is so popular — it doesn't allow the signals inside to interact with signals and conductors outside the line. Twin-lead, on the other hand, has to be kept well away (a few line widths is sufficient) from other feed lines and any kind of metal surface. Why use twin-lead? It generally has lower losses than coax, so is a better choice when signal loss is an important consideration.

SKIN EFFECT

Above about 1 kHz, AC currents flow in an increasingly thin layer along the surface of conductors.

This is the skin effect (**https://en.wikipedia.org/wiki/Skin_effect**).

It occurs because eddy currents inside the conductor create magnetic fields that push current to the outer surface of the conductor. At 1 MHz in copper, most current is restricted to the conductor's outer 0.1 mm, and by 1 GHz, current is squeezed into a layer just a few µm thick.

CHARACTERISTIC IMPEDANCE

Both kinds of transmission lines are specified as having a characteristic impedance, represented by Z_0. For example, popular RG-58 cable is designated to be a 50Ω cable, RG-6 is a 75Ω cable, and so on. If you measure the cable with an ohmmeter, you'll just get a reading of a few ohms. What's going on?

Z_0 applies to how EM waves flow through the cable, and it depends on the size of the conductors, the relative placement of the conductors, and the type of dielectric between them. (Formulas for Z_0 can be found online and in most RF engineering references.) Sometimes referred to as surge impedance, the characteristic impedance determines how the EM wave's energy is allocated between the electric and magnetic field as it travels along the cable.

You can experience acoustic characteristic impedance for yourself with a common soft drink straw and a small diameter straw such as for mixed drinks. Blow a short puff of air through each and feel the resistance from the straw at the rising edge of the pulse. The larger straw allows more air to flow due to its lower impedance which you experience as back pressure resisting air flow. This analogy isn't exact but illustrates the general idea. If a short pulse of voltage is applied to a high Z_0 cable such as 300Ω twin-lead, the resulting current surge in the cable will be lower than for a low Z_0 cable such as 50Ω coax.

Characteristic impedance is important because of how energy gets into and out of a transmission line. As an EM wave travels — in space, along a wire, in a transmission line — any change in Z_0 causes some of the energy in the wave to be reflected in the opposite direction to the wave's travel. The bigger the difference in Z_0, the more energy is reflected. Whether the new Z_0 is higher or lower determines the phase of the electric and magnetic fields of the reflected wave with respect to the forward wave.

Reading between the lines, so to speak, if an antenna or circuit or other load is attached to the line and has an impedance equal to Z_0, all of the power traveling down the line will be transferred to whatever is attached. That's exactly what you want if you're transmitting a radio signal — for all of the transmitter's output to be transferred to the antenna where it is radiated away into space. Similarly, you want Z_0 to match in the receiving direction so that all of that extremely weak signal picked up by the antenna is transferred to the line and thus carried to the receiver. (Transmission lines connected to antennas are usually just called "feed lines.")

REFLECTIONS ON STANDING WAVE RATIO (SWR)

The condition in which the impedance of whatever is attached to the feed line equals Z_0 of the line is called matched. If the impedances are not equal, that's a mismatch. In most cases, Z_0 is not exactly matched and so there are EM waves traveling up and down the cable, bouncing back and forth between the terminations at each end of the line. The device that applies power to the line is called the generator, and the device that takes power from the line is the load. Forward refers to the direction from the generator to the load, and reflected refers to the opposite direction.

These waves set up an interference pattern that is stationary within the cable called standing waves. If all of the power is reflected at one end of the line, the pattern will include points at which the electric fields of the forward and reflected waves are out of phase and completely cancel — resulting in zero voltage. One-half wavelength away, the waves are in phase and add, thus doubling the voltage. **Figure 2** shows a calculated example of standing waves in which the load impedance is four times higher than the line's, reflecting a portion of the forward wave.

You can see a neat flame-based visualization of standing pressure waves in the YouTube video at **www.youtube.com/watch?v=6jfU74enV_w**.

Think pressure = voltage and you've got it!

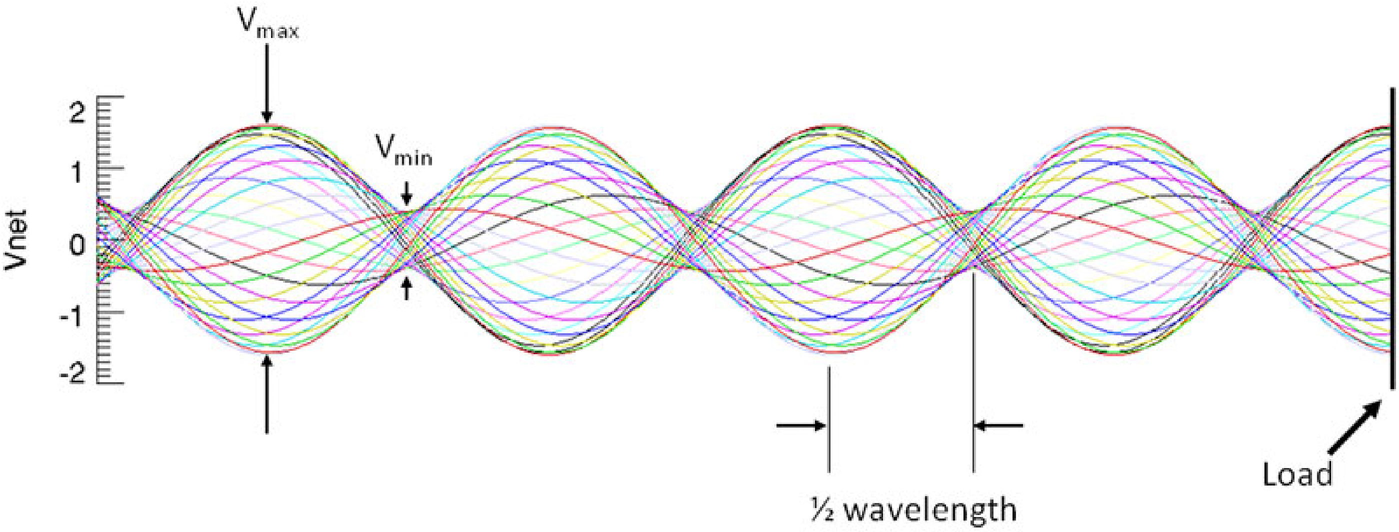


FIGURE 2. Standing waves on a transmission line, with the resulting voltages (VNET) shown in different colors during one complete cycle of the applied voltage. The generated wave with an amplitude of 1 travels from left to right and is partially reflected by the load at right. SWR = V_{MAX} / V_{MIN} = 1.6 / 0.4 = 4.0. *(Graphic created by Wikipedia contributor, Interferometrist and is used under the Creative Commons Attribution-Share Alike 4.0 International license.)*

The ratio of the maximum and minimum voltages is the SWR. (If the SWR is calculated from the voltage, it is VSWR, and it can also be calculated from the standing waves of current as ISWR. The usual convention is to assume that references to SWR mean VSWR.) SWR is always equal to or greater than 1, and is written as a ratio such as 1:1 or 1.5:1 or 3:1, and so forth.

SWR can also be calculated as the ratio of the feed line Z_0 and the load impedance — whichever is greater than 1. Since you already know the feed line's Z_0 and can measure the load's impedance, this is a lot more convenient than trying to measure maximum and minimum voltage inside the line:

$$SWR = \frac{V_{\max}}{V_{\min}}$$

$$SWR = \frac{Z_0}{Z_{load}} \, or \, \frac{Z_{load}}{Z_0}, \; whichever\; is\; greater\; than\, 1$$

Another convenient way to measure SWR is by using forward power (P_f) traveling from the generator to the load and reflected power (P_r) traveling in the opposite direction:

$$SWR = \frac{1+\sqrt{P_r / P_f}}{1-\sqrt{P_r / P_f}}$$

Figure 3 shows a chart that converts any combination of forward and reflected power into an SWR value.

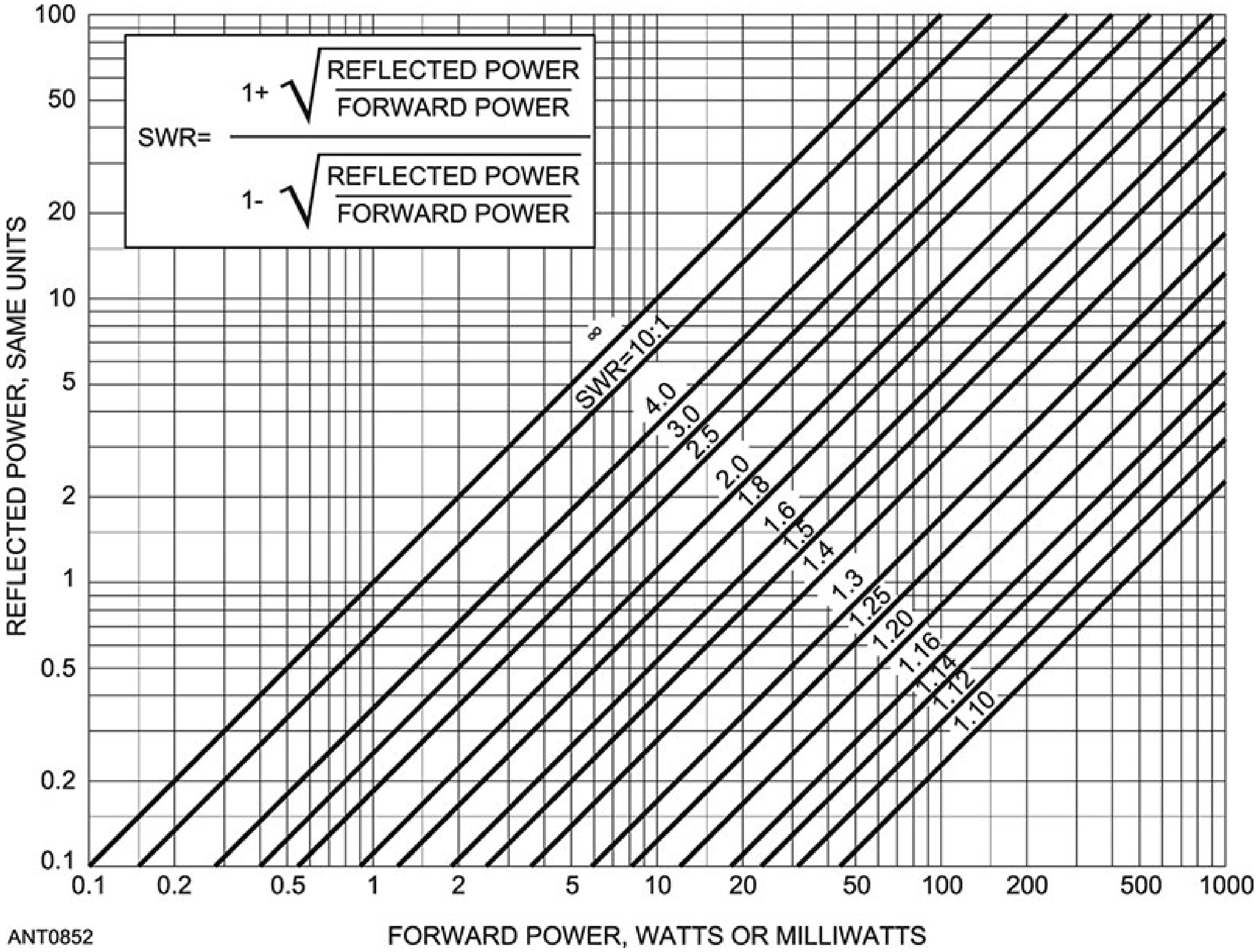


FIGURE 3. SWR as a function of forward and reflected power. *(Graphic courtesy of the American Radio Relay League.)*

SIMILARITIES IN WAVE BEHAVIOUR

This column only touches on how transmission lines actually work in order to discuss some of the common instruments you'll find in the ham station for working with impedance mismatches.

A much better presentation is available from the AT&T Tech Channel at **http://www.youtube.com/watch?v=DovunOxlY1k**.

Called "Similarities in Wave Behavior," the tutorial uses a clever mechanical simulator called the Shive Wave Machine to show just how waves move in transmission lines, including reflection and standing waves. Some simple demonstrations illustrate the idea of SWR and what it measures. If transmission lines seem confusing, watch this video as a great place to start learning.

EFFECTS OF SWR (RADIO AND NON-RADIO)

Why do we care so much about SWR? A clue was provided earlier in explaining that if the characteristic impedance of a line does not match the impedance of whatever load it is attached to, some of the power applied to the line is reflected at the load. Since we would like all of our expensive transmitter output power to be put to work as a radiated signal, it would be good to minimize reflected power at the load. SWR is just a convenient way to measure the quality of the impedance match between our line and the load. The lower the SWR, the better the match!

Non-radio folks also care about SWR — especially with regard to high speed digital data. Data signals may "just" be voltage levels corresponding to 0 and 1, but it takes very high frequency components to make the sharp edges and narrow pulses our designs require.

A 100 Mbit/s data stream contains signal components in excess of 1 GHz! At those frequencies, every wire and PCB (printed circuit board) signal trace has to be treated as a type of parallel-conductor transmission line because it is.

If the Z_0 of a PCB trace does not match the output impedance of whatever circuit is generating the signal or the input impedance of whatever is receiving the signal, severe ringing, overshoot, undershoot, or multiple false transitions and glitches can occur. Search for application notes on "signal integrity" for detailed information about what PCB designers must do to control the data paths at today's signalling rates.

Video signals — particularly analogue video — can suffer from impedance mismatches, resulting in ghost images and distorted pictures. The solution is to understand when transmission line considerations apply and terminate the signal traces in appropriately.

MEASURING IMPEDANCE AND SWR

To make accurate measurements at RF, instruments must be designed for that purpose. Low frequency multimeters simply can't be used. Nevertheless, inexpensive versions are available that don't cost a lot and still provide useful information. You just have to know where to shop!

SWR METERS

The most common transmission line instrument in a ham or CB station is the basic SWR meter shown in **Figure 4A**. The meter is used by setting the CAL control for a full-scale reading for forward power (FWD), then switching to the reflected (REF) position to read SWR. The meter sensitivity varies with frequency, requiring readjustment when using different bands; accuracy is low compared to a lab instrument. Available online and from CB shops for under $30, these meters give a good idea whether SWR is high or not, and are useful in monitoring output power while operating or when adjusting an antenna.

FIGURE 4. Inexpensive SWR meters **(Top)** are useful up to about 30 MHz at power levels up to 100 watts. The more expensive meter **(Bottom)** displays forward and reflected power simultaneously along with SWR on a crossed-needle display.

More advanced meters like the Daiwa CN-101 in **Figure 4B** provide simultaneous power and SWR measurements with a crossed-needle meter. The unit displays both forward and reflected power with independent meter movements. Curves on the meter face indicate SWR at the point where the needles cross. (The curves are the meter equivalent of the chart in **Figure 3** or the equation for SWR in terms of forward and reflected power.) Accuracy of this type of instrument — typically costing around $100 — is quite a bit better, no calibration adjustments are required over the specified frequency range, and the meters can handle the full amateur legal power of 1.5 kW in several ranges. Similar units are available for VHF and UHF operation.

These meters work by coupling a small amount of power from the main feed line into a diode detector circuit. One circuit senses forward power and another senses reflected power — each driving an analog meter. The meters and SWR values are calibrated based on typical diode characteristics, and accuracies of a few percent are about as good as can be expected. This is not up to lab standards but good enough for day-to-day operation, and repeatable enough to compare antennas. Digital meters are also available which digitize the detector output signals and compute SWR for display as a numeric value.

DIRECTIONAL RF WATTMETERS

A step up in accuracy from the SWR meters, directional RF wattmeters — such as my Bird Model 43 shown in **Figure 5** — measure forward and reflected power independently. A sensing element is inserted into the front of the meter and rotated according to the arrow to read power in the desired direction. The meter's user can then convert the readings into SWR, if desired.

FIGURE 5. Bird Model 43 has been in use for a long time, but still provides reliable readings of forward and reverse power using a collection of elements that span 2 to 1,000 MHz

Most hams and technicians only use SWR as an indication of whether excess reflected power is present, so an accurate display of reflected power serves the same purpose as an SWR value.

Sensing elements are calibrated for different power levels and frequency ranges. The list of Bird elements — also known as "slugs" — is available at www.birdrf.com via the Model 43 product sheet. Elements are available at frequencies from 2 to 1,000 MHz, and maximum power levels to 5,000W. Wide-range meters with digital displays are also available that perform the same functions automatically using a microprocessor.

MEASURING IMPEDANCE DIRECTLY

Until relatively recently, making an accurate measurement of impedance at RF required some serious lab instrumentation. Impedance measurements vary with frequency, and can be upset by "stray" capacitance and even lead length of the measuring probe. Based on microprocessor technology developed for the mobile phone, manufacturers are now supplying impedance meters that provide excellent accuracy, record data for later analysis, and display the measurements in numerous formats.

The simplest type is called a "one-port vector impedance meter" as shown in **Figure 6**. This handheld instrument is about the size of a smartphone, costs under $500, and has a colour display that can show the data as impedance, SWR, or in other formats across several decades of frequency. The word "vector" signifies that the meter measures both magnitude and phase of the unknown impedance. These pocket-sized units are especially handy for field use.

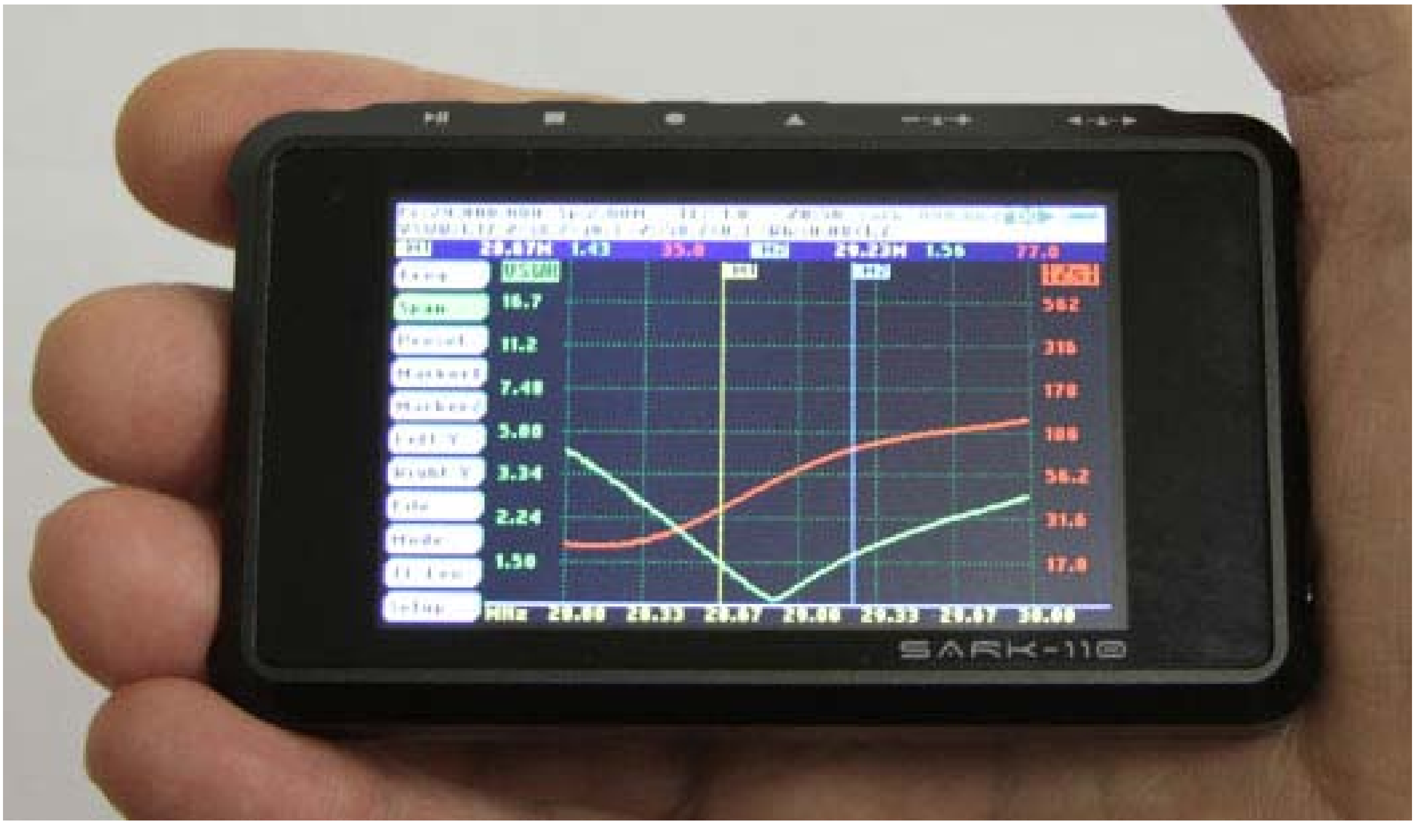


FIGURE 6. The SARK-110 Antenna Analyser is a miniature vector impedance meter that displays several types of measurements from 0.1 to 230 MHz Data can be saved for future analysis on a PC, as well. *(Photo courtesy of SteppIR.com.)*

A more capable instrument is the two-port vector network analyser, or VNA shown in **Figure 7**. Where the one-port model can only measure whatever is attached at the single connector, the VNA can generate a signal, pass it through a circuit or cable, and measure how it is amplified, attenuated, phase-shifted, etc. VNAs used to be found only in engineering and research facilities, and cost $10,000 or more. Now, you can buy units specified for use through 1 GHz for under $1,000. These units are designed to be used on the workbench with a host PC.

FIGURE 7. The DG8SAQ Vector Network Analyser not only measures impedance through 1.2 GHz but also makes gain, loss, and phase measurements of circuits and transmission lines. A laptop or other host PC is required to process the measurements taken by the unit shown in the photo. *(Photo courtesy of SDRKits.com.)*

Once you have the ability to measure impedance and power in a transmission line, many powerful techniques are available to turn the data into an understanding of what's going on "in there." In turn, this allows you to design and troubleshoot your antenna or data transmission system. Transmission lines become a lot easier to work with once you have the ability to make the right measurements!

CORRECTING FOR SWR

Finally, what can you do about SWR if you have too much of it? That's a loaded question since how much is too much depends on the application. Nevertheless, in the next column we'll take a look at techniques used by hams to reduce SWR by transforming and matching impedances across a wide range of frequencies. **NV**

GREAT LENGTHS ON LINES

Transmission lines are one of the most written-about topics in all of ham radio. More than just ways of carrying RF energy from place to place, they can act as filters and impedance transformers, too. Who knew that a simple "wire" could do all these tricks?

You can learn a lot more about them via the ARRL's Technical Information Service's web page at **www.arrl.org/transmission-lines**.

Alf Traeger and the Pedal Radio

The work of Alfred Traeger OBE (1895-1980) is an example of how medical science, ideas and technology interacted to make a remarkable difference to the lives of people living in isolated rural areas. This reveals how a practical approach to problem-solving and religious faith played significant roles in the achievements of Traeger and his colleague the Reverend John Flynn along with the board and staff of the Australian Inland Mission (AIM). The support and backing of businessmen and community groups in the technological developments would then provide a mantle of safety to the people of the Australian outback, assist in the development of the School of the Air and provide much valued social support.

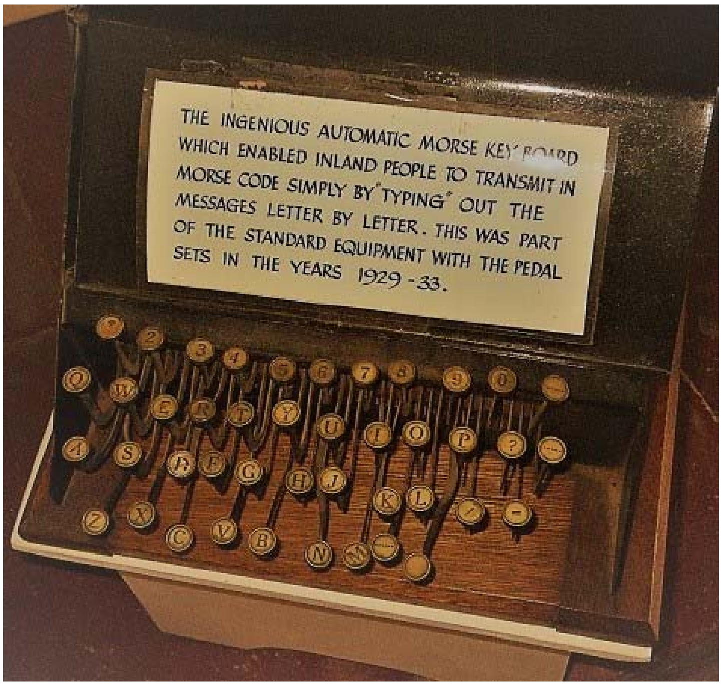
Alfred, known as Alf, was born on 2 August 1895, in the Dimboola district of Victoria, to Johann Hermann Traeger and Pauline Louise, nee Zerna. When Alf was 12 the family moved to the family farm near Balaklava where his grandparents had settled after migrating from Germany in 1848. Alf's inventiveness and ability was evident when he built a telephone line from the house to the implement shed 50 metres away, using items found around the farm.

The family moved to Adelaide where Alf attended Martin Luther School and at 16 he began a four year course in Mechanical and Electrical Engineering at the Adelaide School of Mines. Before his graduation he had built a radio transmitter and was sending Morse code messages at 20 words a minute. After working in the Tramways workshop and at the General Post Office as a mechanic and telephonist, he got a job in Hannan Brothers workshop, where he serviced car and truck generators. He attended Bethlehem Lutheran Church and was a radio ham in his spare time.
The Reverend John Flynn (1880-1951) was greatly concerned about health issues for many Outback people and in 1912 he was appointed inaugural Superintendent of the AIM. Flynn had a vision to provide a mantle of safety by using nurses to set up bush hospitals in remote places and employing flying doctors. This required aircraft, infrastructure and communication so the people could make contact with the base station.

In June 1925, Flynn purchased a 600 volt generator from Traeger. This was mounted on the splashboard of a Dodge buckboard and the generator was driven by a belt with a pulley attached to the rear wheel when jacked up. They loaded with a transmitter, accumulators, dry batteries, shortwave receivers, a broadcast receiver and aerial, they set out for Beltana, Innamincka, Birdsville, Marree and Alice Springs. On this trip they learnt that Morse code was the only reliable means of communication in the Outback.

Flynn concentrated on building a hospital in Alice Springs, but continued working on the radio project. Back in Adelaide he met Harry Kauper, the senior engineer at the new 5CL radio station, who offered the 5CL workshop to the team. Traeger was taken on as an assistant and together they assembled two outpost sets and tested Edison copper oxide batteries for transmitting power. Ernest Fisk of AWA in Sydney was very generous with his support and offered the AIM Board a gift of the experimental base station in Alice Springs.

Morse code keyboard   Photo: David Hewitt



In October 1926 Traeger went to Alice Springs with Flynn. Staying in the AIM Nursing Home he set up the first outback aerial mast behind the building and assembled the experimental mother base in the engine room. He set up a 32 volt lighting plant to provide power and carried out experiments with baby sets and successfully contacted Kauper in Adelaide. On 11 November the buckboard was loaded with wireless gear, aerial poles and nine heavy duty batteries and they set off to Hermannsburg Mission, 130 km away. Their much anticipated first attempt to send a message to Alice Springs was made, but failed due to having a wrong coil. They began teaching Pastor Albrecht as much Morse code as they could. In Alice Springs with the correct coil they finally achieved bush communication by radio.

At the Arltunga Police Station, about 150km east of Alice Springs, the other baby set was installed, followed by another two outposts enabling daily contact with Alice Springs. A Morse code message sent from Hermannsburg to Alice Springs was transmitted to Tanunda as a telegram to Mrs Albrecht, there with her newborn baby who needed treatment. This success provided a vision of future possibilities.

Traeger was appointed as the Radio Engineer by the AIM board, because they knew that further developmental work was needed such as a hand-driven generator, produced with the help of the staff at the Adelaide Foundry.

In 1927, Flynn and Traeger were back on the road to Cloncurry in Queensland. They visited other settlements including Mornington Island and in November provided an example of how this communication equipment would also affect social and recreational life by gathering locals to listen to the Melbourne Cup.

In 1928 AIM's Aerial Medical Service was established at its first base in Cloncurry where there was a hospital, telegraph service and was serviced by Qantas. A De Havilland DH50A was modified by Qantas. Flying Doctor flights would be made with a pilot, a nurse and the authorising doctor. The homestead owners were required to make an airstrip. Sending Morse code messages using hand-winding machines was proving difficult for housewives in remote homesteads and also for the nursing sisters.
On his 33rd birthday Traeger declared that he would buy bicycle pedals to drive the generators. Based on his drawings, Reg Cox of the Machinery and Electrical Company in Sydney constructed twelve generator units and nickel-plated bicycle pedals were obtained from the Malvern Star Company.
By mid-November the famous photo of Traeger dressed in his suit and operating the pedal radio was taken.

With a team of new recruits from Bethlehem Church working with Harry Kinsbrunner, base operator in Cloncurry, they installed and tested a mother station in the vestry of the local church. Six baby sets were then installed in stations spread over an area of 90,000 square miles. Traeger installed the No.1 pedal set at Augusta Downs Station and taught the station manager's wife, Gertrude Rothery, how to use and maintain it. She was the first person to use the pedal wireless, sending a message to Kinsbrunner in Cloncurry and a telegram to Flynn in Sydney.

New equipment needed funding which came from pastoralists, such as Sidney Kidman, stock and station agents, AWA and the Country Women's Association (CWA). The local postmaster at Cloncurry, Eric Hastwell, became a close friend of Traeger and they exchanged ideas about how to make improvements. They observed the stress in some operators and knew that a better way of sending Morse code was needed. By 1931 Traeger had developed a Morse code automatic keyboard which looked like a standard typewriter but used a spring-operated drum and perforated strip to produce the Morse character. Traeger impressed members of the AIM Board when he demonstrated it and they approved 20 sets and more if needed. These were in use for many years and later used for emergency back-up. In the early 1930s Traeger's field trips to set up pedal radio highlighted the need to develop a mobile pedal set so they could communicate from the roadside. Flynn recommended to the AIM board that Traeger should design and develop such a transceiver and within a year he produced one that could be carried by truck, horse or camel.

The next development was to replace Morse code with voice telephony. A concern was raised that homestead owners were unlicensed wireless operators. Traeger was involved in negotiations and amateur radio licenses were issued. Radio telephony was introduced to the Cloncurry network by 1935 and people could now chat to each other and the Flying Doctor could talk mid-air to patients and colleagues. This was a great triumph for Traeger. Traeger was commissioned to build base radio stations in Port Hedland in the Pilbara region and at Wyndham in the Kimberley region. The shipping of masts and radio equipment was financed by the Dalgety Pastoral Company. The Flying Doctor organisation had emerged as a separate entity from the Presbyterian Synod and it became The Royal Flying Doctor Service in 1955.

Now living in Adelaide, Traeger became an independent radio contractor and set up a new factory in Marryatville, known as Traeger Transceivers. His plan was to replace the pedal generator with a mechanical device using a 6 volt car battery. The news of the declaration of the Second World War was spread around the Outback by the network of Traeger wireless sets and sought by the Army for communications on the North Australian coast.

In 1932, aged 42, Traeger married Olga Schodde, whom he met at Bethlehem Lutheran Church. They had 2 daughters, Pauline and Anne, who were only eight and six when sadly Olga died prematurely. In 1956, at age 61, Traeger married Joyce Mibus, a widow with two young daughters, Suzanne and Glenda. Joyce and Alf's son, Michael, was born in 1958.

In the post-war years Traeger was asked to help an Australian doctor set up an aerial medical service in Nigeria and within 6 months his dedicated team in the Marryatville workshop produced twenty sets suited to African conditions. By 1962 in the most distant Flying Doctor area of the Eastern Goldfields, there were about seventy fixed outposts and several hundred portable devices. These devices were also used by the CWA, the School of the Air and the Isolated Children's Parents Association. The Charleville School of the Air daily roll call was 300!

A practical down-to-earth solution to the challenge posed by the need to get emergency medical help at night time when the mother station was closed, was the use of a two tone call on a tin whistle which was decoded when transmitted to the base station, released an electrical impulse, tripped a relay and rang an alarm bell to alert the base operator to turn on the transmitter. An aid developed by Sister Garlick for use by the Flying Doctor was a chart showing the human trunk divided into sections by numbers for easy identification of the pain or injury.

By the mid-fifties and into the 1960's solid state circuits and greatly improved batteries had been developed as well as new plastics and lightweight alloys. Traeger's colleagues in the Outback could now drive 4WD vehicles.

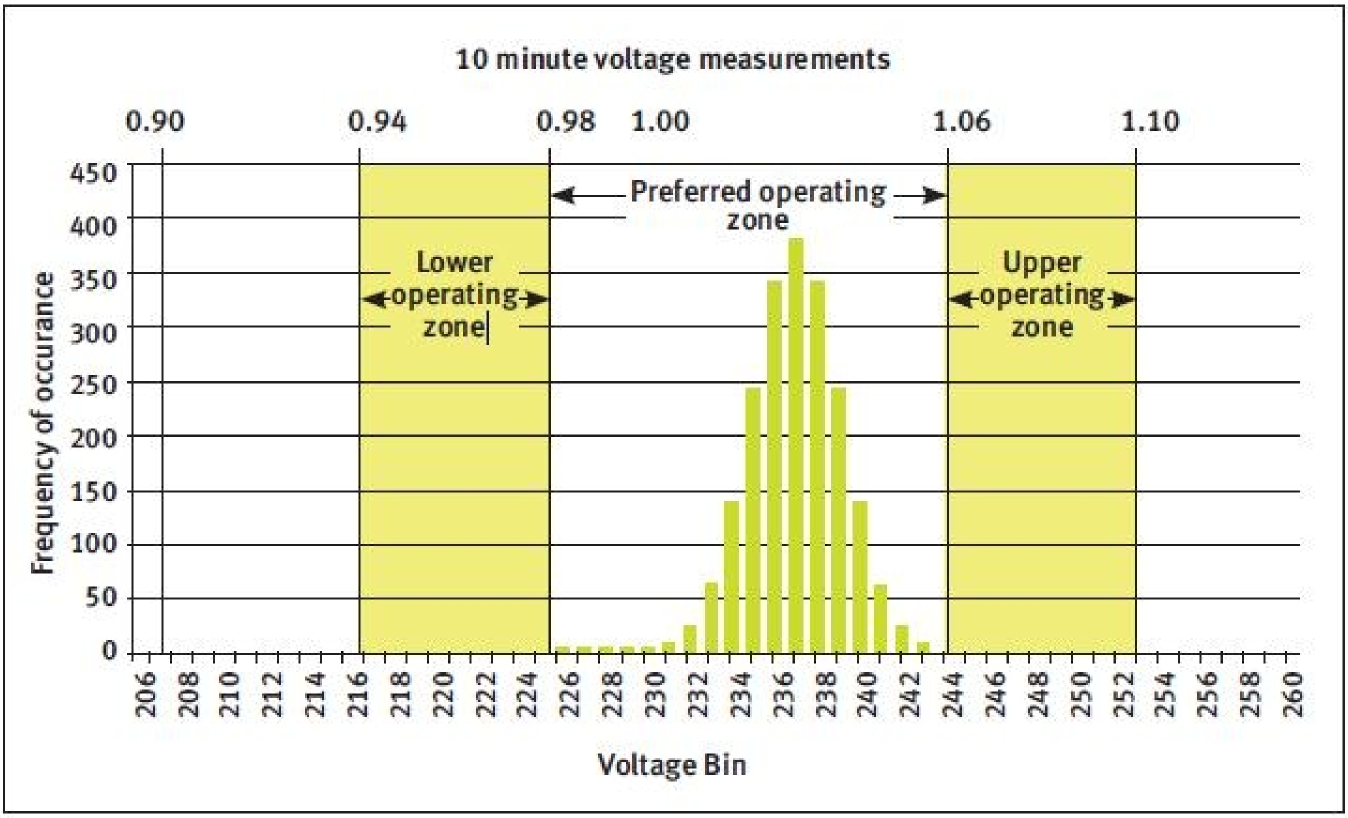
In 1944 Traeger received an OBE medal and he also received several other honours. He did not seek great financial gain from his endeavours and was a man of quiet faith. Traeger Transceivers Pty Ltd closed in 1974. Traeger died on 30 September 1980. Memorials to Alfred Traeger, the wireless wizard, can be seen in Balaklava, Alice Springs, Dimboola Shire, Cloncurry, Townsville and Port Augusta. The Australian twenty dollar note has an image of Flynn, the body chart and Traeger's pedal radio. However, his greatest memorial must be his legacy of care to the people in the Australian Outback.

~Naomi Muegge Friends of Lutheran Archives Inc. Newsletter

WHEN VOLTAGE VARIES

BY PAUL SKELTON

The nominal low-voltage level in Australia is now 230V, since 2013.



The nominal voltage in Australia was set at 240V in the 1920s. However, a change began in 1980 with the International Electrotechnical Committee (IEC) deciding to rationalise the 220V, 230V and 240V nominal voltage levels around the world to a consistent 230V.

This rationalisation was ostensibly made to improve the economics of making appliances by allowing manufacturers to produce a range of items with a rated voltage of 230V. In 2000, Standards Australia issued a system Standard, AS60038, with 230V as the nominal voltage with a +10% to –6% variation at the point of supply.

AS/NZS3000 (Wiring Rules) allows an additional 5% voltage drop in electrical installations (Clause 3.6.2) that electricians will be well used to calculating. The Wiring Rules recognised the change in nominal voltage level in the 2007 edition at Clause 1.6.2.

The Australian Capital Territory, Queensland and Western Australia have not adopted the new 230V Standard at this stage, but this is not a big concern as the old 240V range of plus or minus 6% fits within the new Standard. Other states have some additional peculiarities, and these should be understood if disputes occur.

It must be remembered that voltage levels always vary as loads cut in and out, so an allowable range of voltage is important.

The new Standard

A new power quality Standard, AS61000.3.100, has recently been released that details requirements additional to the existing systems Standard.

The new Standard stipulates a nominal 230V, and the allowable voltage to the customer's point of supply is, as mentioned, +10% to –6%. However, the preferred operating range is +6% to –2%.

The idea of this preferred operating range is to provide a reasonable voltage for any remaining 240V appliances. A statistical approach has been taken, and the 50 percentile value of voltage is in the preferred operating zone (see accompanying histogram).

The histogram shows the logged voltage along the ‘x’ axis with the logged results included in bins based on the voltage level. Each logged value is counted and the total count displayed on the ‘y’ axis. The bins are divided into operating zones as shown.

To complicate matters, the limits are not hard and fast but based on voltage levels sampled at high speeds and averaged over 10 minutes in accordance with AS/NZS61000.4.30. A statistical approach has also been taken with these limits, the upper limit being based on a 99 percentile value and the lower limit on a 1 percentile.

This means that under normal conditions the average voltage levels over 10 minutes can go above the upper 10% limit for 1% of the time and below the lower –6% limit for 1% of the time.

These limits may be exceeded when the network is not in its normal configuration, such as may occur in storms or bad weather when parts of the network have tripped off and supplies have been rerouted.

The upper operating zone is particularly important given the installation of solar systems on many residential and commercial premises across Australia. Exporting energy from these systems can cause a voltage rise in the installation due to the export current (I) and the impedance of the system (Z), that is, Vrise = I x Z.

An upgrade of the network and/or installation wiring will be called for if the voltage is likely to rise above the upper operating zone at the installation, or because of limits that may be set in state based service rules or relevant Standards.

There has been much discussion in New South Wales on this issue, and the NSW Service and Installation Rules may be the first to limit voltage rise in the installation service wire to 1%.

Utilisation voltage range

The utilisation voltage range is particularly important for appliances and electricians. This is the full range of voltage an appliance should receive, and an electrician should measure it in an installation under normal conditions.

This range takes into account the voltage range allowed at the point of supply and the additional 5% voltage drop in the installation. This equates to a total range of 253V to 205V.

The Wiring Rules specify that a 7% voltage drop may be satisfactory where the point of supply is at the terminals of a substation (Clause 3.6.2), but the additional 2% voltage drop is sacrificed in the LV system and therefore does not increase the utilisation range.

Most appliances and equipment items coming into the country are likely to be stamped as 240V (equipment Standards have been slow to keep up) but may in fact be 230V rated, as they have been designed to IEC Standards that are 230V based.

Practical application of limits

The foregoing discussion may be complicated for those that have not examined the issues in detail, but there is a simple application of limits.

An electrician measuring voltages in an installation should expect levels to be within the utilisation range of 253V to 205V. However, voltage can be above this range under normal conditions for 1% of the time or below for 1% of the time.

If voltage levels are regularly exceeding this range, then the network company or a consultant should be contacted for advice.

I was recently discussing electrical issues with a computer sales and repair company representative. His supply varies regularly from 244V to 239V, triggering the alarm on the uninterruptible power supply (UPS).

A range such as this is acceptable and within the preferred operating range of the Standard. A UPS should not react when voltage goes down to 239V, so the alarm settings need adjusting.

Voltage alarm limits probably should be set to at least the utilisation voltage range, or even wider, to allow for the 1 percentile allowance – say 200V to 258V. Most computerised and electronic equipment should be capable of handling this range of voltage, and possibly more.

It will pay to check the specifications of equipment being connected to the UPS before adjusting the alarm settings.

Testing

All testing should be done in accordance with safe work procedures and legislated requirements. Safety should always be your priority.

A true RMS meter should be used to measure voltages. Older style averaging meters will be inherently inaccurate, as voltage waveforms are non-sinusoidal due to harmonic loads.

Meters and power-quality loggers should be calibrated regularly to ensure accuracy, or any advice given will be questionable.

I am often asked how often meters should be calibrated, but this should be discussed with your calibration company. Its advice should be based on how your particular make and model of meter holds its calibration, and the conditions under which it is likely to be used. The typical calibration period is 12 months.

A multimeter can be used for measuring voltage levels in an installation, but this will provide only a spot indication of voltage. A powerquality logger will generally be needed to sort out voltage problems or to check compliance with the new 230V Standard.

The problem being experienced will determine the installation location of the logging instrument, and it is always best to install the logger at the piece of equipment experiencing problems.

A Class A power-quality logger will be required to ensure compliance with AS 61000.3.100 if the supply is suspect, and it will need to be installed for at least one week. Class B instruments are great for locating faults but may not be adequate should a dispute arise.

Conclusion

Australia has a 230V Standard that has not been universally adopted across the country. State-based requirements may need to be checked. Voltage levels in installations will generally be within the utilisation range of 253V to 205V and may go above or below these limits for short periods.

Although this range is quite large, 230V rated equipment should be capable of coping with it. Some assistance is built into AS61000.3.100 for old 240V appliances and equipment, with the 50 percentile value preferably lying within the range of 244V to 225V.

Those who compile specifications for equipment purchases should seek equipment that can cope with at least the utilisation range mentioned above, and it would pay to note that the range is based on 1 and 99 percentile values under normal conditions. Reference to AS61000.3.100 and AS/NZS3000 is recommended in specifications.

Compliance with the new 230V power quality Standard can be checked only with a Class A power-quality logger over a log period of at least one week. Test instruments should be true RMS and regularly calibrated.

Voltage drop calculations should now be made using 230V instead of the 240V as provided by Wiring Rules clauses such as 1.6 and 3.6, and not withstanding such clauses as 1.6.4 and 1.7. Check these clauses if you are not fully conversant with them. The voltage levels that customers and their equipment receive don’t constitute an easy issue – but then probably never did.

~Electrical Consulting and Training *chris@elect.com.au*

NEVARC Nets

40M Net

Monday, Wednesday and Fridays
10am Local time (East coast)
7.095 MHz LSB
Approximately + or - QRM
Hosted by Ron VK3 AHR

80M Net

Wednesday 20:30 Local time
3.622 MHz LSB
Hosted by Ron VK3 AHR
Using the club call VK3ANE

2M Nets

Monday at 2000 local time on
VK3RWO repeater
146.975 MHz

President, VK2VU, Gary
Vice President, Tom VK3NXT
Secretary, VK2FKLR, Kathleen
Treasurer, Amy

NEVARC CLUB PROFILE

History

The North East Victoria Amateur Radio Club (NEVARC) formed in 2014.
As of the 7th August 2014, Incorporated, Registered Incorporation number A0061589C.
NEVARC is an affiliated club of the Wireless Institute of Australia.

Meetings

Meetings details are on the club website, the Second Sunday of every month, check for latest scheduled details.
Meetings held at the Belviour Guides Hall, 6 Silva Drive West Wodonga.
Meetings commence with a BBQ (with a donation tin for meat) at 12pm with meeting afterwards.
Members are encouraged to turn up a little earlier for clubroom maintenance.
Call in Via VK3RWO, 146.975, 123 Hz tone.

VK3ANE NETS

HF

7.095 MHz Monday, Wednesday, Friday - 10am Local time
3.622 MHz Wednesday - 8.30pm Local time

VHF

VK3RWO Repeater 146.975 MHz – Monday - 8pm Local time
All nets are hosted by Ron Hanel VK3AHR using the club callsign VK3ANE

Benefits

To provide the opportunity for Amateur Radio Operators and Short Wave Listeners to enhance their hobby through interaction with other Amateur Radio Operators and Short Wave Listeners. Free technology and related presentations, sponsored construction activities, discounted (and sometimes free) equipment, network of likeminded radio and electronics enthusiasts. Excellent club facilities and environment, ample car parking.

Website: **www.nevarc.org.au**

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Postal: **NEVARC Secretary**
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